- **manipulate** information-bearing electric signals with circuits and computers, and
- **receive** electric signals and convert the information expressed by electric signals back into a useful form.

Telegraphy represents the earliest electrical information system, and it dates from 1837. At that time, electrical science was largely empirical, and only those with experience and intuition could develop telegraph systems. Electrical science came of age when James Clerk Maxwell2 proclaimed in 1864 a set of equations that he claimed governed all electrical phenomena. These equations predicted that light was an electromagnetic wave, and that energy could propagate. Because of the complexity of Maxwell's presentation, the development of the telephone in 1876 was due largely to empirical work. Once Heinrich Hertz confirmed Maxwell's prediction of what we now call radio waves in about 1882, Maxwell's equations were simplified by Oliver Heaviside and others, and were widely read. This understanding of fundamentals led to a quick succession of inventions the wireless telegraph (1899), the vacuum tube (1905), and radio broadcasting that marked the true emergence of the communications age.

During the first part of the twentieth century, circuit theory and electromagnetic theory were all an electrical engineer needed to know to be qualified and produce first-rate designs. Consequently, circuit theory served as the foundation and the framework of all of electrical engineering education. At mid-century, three "inventions" changed the ground rules. These were the first public demonstration of the first electronic computer (1946), the invention of the transistor (1947), and the publication of **A Mathematical Theoryof Communication** by Claude Shannon (1948). Although conceived separately, these creations gave birth to the information age, in which digital and analog communication systems interact and compete for design preferences. About twenty years later, the laser was invented, which opened even more design possibilities. Thus, the primary focus shifted from **how** to build communication systems (the circuit theory era) to what communications systems were intended to accomplish. Only once the intended system is specified can an implementation be selected. Today's electrical engineer must be mindful of the system's ultimate goal, and understand the tradeoffs between digital and analog alternatives, and between hardware and software configurations in designing information systems.

Note: Thanks to the translation efforts of Rice University's Disability Support Services , this collection is now available in a Braille-printable version. Please click here5 to download a .zip file containing all the necessary .dxb and image files.

1.2 Signals Represent Information

Whether analog or digital, information is represented by the fundamental quantity in electrical engineering: the **signal**. Stated in mathematical terms, **a signal is merely a function**. Analog signals are continuous-valued; digital signals are discrete-valued.